U.S. Army Corps
of Engineers
Seattle District

Wynoochee Dam
Section 1135 Fish Restoration Project

Grays Harbor County, Washington

Preliminary Draft
Interim Design Report
January 10, 2003

This page intentionally left blank.

Wynoochee Dam
Section 1135 Fish Restoration Project

Grays Harbor County, Washington

Preliminary Draft
Interim Design Report

January 10, 2003

This page intentionally left blank.

Table of Contents

List of Tables

List of Figures

List of 10% Plan Sheets

(The Complete Set of 10% Plan Sheets is Included in Appendix C)

Wynoochee Dam Fish Bypass – 10% Plan Sheet List			
Plate No.	**Sheet No.**	**Title**	**Full Size Sheet Scale**
G1	1	Title Sheet	N/a
G2	2	Project Footprint	N/a
G3	3	Partial Site Plan	N/a
C1	4	Eicher Screen with Penstock Bypass (Alternative 1)	1” = 20’
C2	5	Eicher Screen with Penstock Bypass (Alternative 2)	1” = 20’
C3	6	Eicher Screen with Replaceable Penstock Section (Alternative 3)	1” = 20’
C4	7	Pressurized HDPE Bypass Pipeline	1” = 20’
C5	8	Multi-Level Discharge System (Alternative 1)	1” = 20’
C6	9	Multi-Level Discharge System (Alternative 2)	1” = 20’
C7	10	Plan and Profile, Gravity Flume	1” = 20’
C8	11	Plan and Profile, Gravity Flume	1” = 20’
C9	12	Plan and Profile, Gravity Flume	1” = 20’
C10	13	Plan and Profile, Gravity Flume	1” = 20’
C11	14	Outlet Discharge System (Alternative 2)	1” = 20’
M1	15	Details - Eicher Screen with Penstock Bypass (Alternative 1)	As Noted
M2	16	Details - Eicher Screen with Penstock Bypass (Alternative 2)	As Noted
M3	17	Details - Eicher Screen with Replaceable Penstock (Alternative 3)	As Noted
M4	18	Details - Multi-Level Discharge System (Alternative 1)	As Noted
M5	19	Details - Multi-Level Discharge System (Alternative 2)	As Noted
M6	20	Eicher Screen Details	As Noted
M7	21	Flume Section Details	As Noted

This page intentionally left blank.

1. INTRODUCTION

Wynoochee Dam is located on the Wynoochee River approximately 30 miles due north of the City of Montesano, in Gray's Harbor County Washington. The dam currently does not provide adequate downstream fish passage, and the Seattle District of the U.S. Army Corps of Engineers has initiated the Wynoochee Dam Fish Restoration Project to develop improvements to the dam that will provide adequate downstream fish passage.

1.1 Project Location

The project is located in Section 20, Township 22 North, Range 7 West, in Gray's Harbor County, Washington [USGS Wynoochee Lake quadrangle]. The existing fish trap facility and barrier dam are located at Wynoochee river mile 49.6, while the Wynoochee Dam is located further upstream at Wynoochee river mile 51.8. The Wynoochee Dam is located approximately 30 miles due north of the City of Montesano. Plan Sheet 1 in Appendix C includes a vicinity map and a project site map.

1.2 Project Authorization

The Wynoochee Dam Fish Restoration Project is being conducted under Section 1135 of the Water Resources Development Act of 1986, by the U.S. Army Corps of Engineers (USACE), Seattle District

1.3 Previous Studies

This *"Interim Design Report"* represents a continuation of and expands upon work previously conducted by others (United States Army Corps of Engineers, Harza Northwest, and the Tacoma Public Utilities). Most of this previous work is presented in the *Wynoochee Dam Section 1135 Fish Restoration Project; Project Modification Report and Environmental Assessment* (USACE, 1998). The project modification report should be referenced for additional information on the project history, resource problems and opportunities, project conditions, the project selection process, and the initial development of the hydraulic and biological design criteria.

During the development of the *Wynoochee Dam Section 1135 Fish Restoration Project; Project Modification Report and Environmental Assessment*, staff from the Washington Department of Fisheries and the National Marine Fisheries Service provided twenty-five criteria for hydraulic conditions to be met throughout the bypass system. These criteria were based on the environmental requirement of the fish that are to be passed through the system (USACE, 1998).

For the *"Interim Design Report"*, a technical committee (Wynoochee Dam Technical Committee) comprised of staff from the United States Army Corps of Engineers (USACE), Tacoma Public Utilities (TPU), Washington Department of Fish and Wildlife (WDFW), United States Forest Service (USFS), and Tetra Tech (TT) met to review the previously established hydraulic and biological design criteria. This meeting was conducted on October 18th, 2002. The meeting provided an opportunity for a thorough discussion of each of the criterion and an opportunity to recommended changes to the criteria when applicable. The meeting resulted in the production of a revised set of design criteria, which were subsequently used in the development of the project features discussed in this report. The revised criteria are included in Appendix A of this report.

1.4 Project Purpose

The current report phase of the project is the development of this *"Interim Design Report"*, which identifies and develops project features to the 10% level of design, and presents the designs in a detailed narrative. The design is supported by Biological and Hydraulic Design Criteria (Appendix A), Hydraulic Analyses (Appendix B), Geotechnical Analyses (Appendix E) and notes and photographs from field reconnaissance of an existing Eicher screen installation (Appendix F). Conceptual (10%) design plans (Appendix C) and preliminary cost estimates (Appendix D) were also developed in support of this report. The *"Interim Design Report"* will provide the basis for identifying a recommended alternative and developing this recommended alternative to a 35% level of design.

2. PROJECT ELEMENTS

The proposed downstream fish bypass facility begins at the Wynoochee Dam intake structure. In the current condition, downstream fish migration of salmon and steelhead does occur at Wynoochee Dam; however studies by Washington Department of Fisheries (WDF) and the University of Washington indicate that there is approximately a 14% loss of coho smolts and a 28% loss of steelhead and cutthroat smolts as a result of passage through the dam low level outlets (Dunn 1978). Additionally, a portion of the downstream migrants do no pass through the dam, but stay in the reservoir, a problem known as residualization. Large numbers of coho and steelhead have been found during reservoir trapping studies. The residualization is thought to be caused by poor configuration of the downstream passage system at the dam. Smolts were found to mill inside the wetwell during a 1995 test and were found to have difficulty getting to the depth of the penstock (USACE, 1998).

In the proposed project condition, fish entering the penstock would move down gradient to the proposed penstock Eicher screen, and would be diverted into a pressurized bypass pipe. This pipe would carry the fish across a U.S. Forest Service (USFS) vehicle bridge to a multi-level discharge system, where, on occasion, fish may be collected for testing purposes. From this point of discharge, the fish would be transferred into a gravity flume, traveling down gradient to a series of transitional ponds, before they are allowed to enter the Wynoochee River. The transitional ponds would also function as a potential site for fish collection during survival testing. Modifications that are not directly related to the fish bypass facility include proposed structural modifications to the existing adult fish trap facility, located approximately two miles downstream of the dam. Proposed modifications will improve the current sorting and upstream transport process of wild and hatchery fish. Two fish supplementation ponds are also proposed to improve the survival quality of existing hatchery fish.

The project features are briefly summarized below, in an upstream to downstream sequence. In subsequent sections of the report, each feature is described in more detail, along with additional discussion on key assumptions that were used in the development of the project features, alternative approaches to the development of the feature, and preliminary cost estimates of each feature. Supporting calculations for the preliminary cost estimates are included in Appendix D.

- **Intake Wetwell and Gate Shaft**: There are currently two alternative points of entry for fish to enter the Wynoochee Dam penstock. Prior to 1997, the only way for downstream migrating fish to enter the penstock was to be swept vertically down through the existing wetwell and into the penstock, which has a centerline elevation of 736 feet. In 1997, the City of Tacoma Public Utilities (TPU) cut a temporary 5-foot high by 9-foot wide opening, with a centerline elevation of 777 feet, in the wall between the wetwell and the gateshaft. This higher-level opening was constructed to improve attraction conditions for fish as they continue their downstream migration.

  Results of testing in 1997 by TPU indicated that the higher-level opening was extremely effective in attracting and transporting fish to and through the penstock. However, later testing also indicated that fish still continued to utilize the existing wetwell entrance to the penstock (USACE, 1998). Modifications to the intake structure that were considered at this level of design included either removal and sealing of the higher level opening or making the necessary improvements to the opening to make it a permanent feature of the fish bypass system.

- **Penstock Eicher Screen**: An Eicher screen is a pivoting screen positioned within the cross-sectional area of a penstock that allows water to flow both through and parallel to the screen. Water flowing through the screen is conveyed to the turbines, while the fish bearing water flowing parallel to the screen surface is sent to a bypass pipeline. A primary assumption of this report is that the Eicher screen is the selected fish screen for this application, and that no other screen types are to be considered. It is proposed that an Eicher screen be installed in the existing penstock, approximately 250 feet downstream of the penstock intake. The existing penstock is located on the west side of the Wynoochee River. Existing flows through the penstock range between 210 and

1,300 cfs, however, flows through the penstock when the Eicher screen is in place are expected to range between 210 cfs and 800 cfs (Criterion #1).

- **Pressure Bypass Pipe**: The pressure bypass pipe is connected to the crown of the penstock, at the downstream end of the Eicher screen. The pipe carries the bypass discharge and the downstream migrating fish to the opposite side of the Wynoochee River. The crossing of the river will be accomplished by suspending the pipeline beneath the existing USFS Road 2294 bridge structure. The pressure bypass pipe will discharge into the next downstream component of the bypass system, the proposed multi-level discharge system. High-density polyethylene (HDPE) material will be used for the bypass pipeline, due to it's smooth interior surface (Criterion #8). The magnitude of flows that are anticipated through the bypass system will range between approximately 20 cfs and 35 cfs, which were computed from the allowable range of velocities in the pressure bypass pipe (Criterion #5, #10, and #11).

- **Multi-Level Discharge to System**: The need to operate the fish bypass facility with varying reservoir pool elevations (760 ft to 800 ft) and varying penstock flows (210 cfs to 800 cfs) required the development of a project feature that will provide operational flexibility during changing hydraulic conditions. At the terminus of the pressure bypass pipe, prior to discharge to the gravity flume, a multi-level discharge system is proposed. This system is comprised of multiple pressure outlet pipes set at different elevations that will discharge to the gravity flume. The multi-level discharge system will allow for the single pressure bypass pipeline described above to be connected to one of the pressure outlet pipes. The decision as to which outlet pipe to connect to will be dependent on the reservoir pool elevation and the penstock flow rate at the time of operation.

- **Gravity Flume**: A gravity flume will start at the outlet of the multi-level discharge system and will maintain open channel flow conditions for the entire 1,800 foot length. Surfaces and joints will be made smooth to prevent injury to fish. The flume will maintain supercritical flow throughout the alignment (Criterion #13), and will maintain a minimum nominal flow depth of 9 inches (Criterion #14). The gravity flume will convey the bypass flow and the downstream migrating fish from the multi-level discharge system to the transitional ponds.

- **Discharge Outlet System**: The discharge outlet system is located at the terminus of the gravity flume and consists of a series of transitional ponds, connected by an open channel. The downstream-most transitional pond will have two outlets to the Wynoochee River. The first outlet will be a piped outlet that will "siphon" off a majority of the bypass flow. A screen at the inlet of the pipe will prevent fish from entering. The second outlet will be an open channel system that will discharge the remaining bypass flow and the fish directly into the Wynoochee River. The second outlet to the Wynoochee River is located just downstream of the existing USGS gauging station.

- **Fish Survival Test Facilities**: The fish survival test facilities are required to allow for the examination of fish as they pass through the bypass system, so as to ascertain mortality levels. These facilities are proposed to be incorporated into the construction of the transitional ponds, which corresponds to the downstream-most portion of the bypass system.

- **Supplementation Ponds**: Two small conditioning ponds are proposed for implementation. One pond would host 25,000 winter run steelhead (5-7 fish/lb.) and the other would host 55,700 coho salmon (16-18 fish/lb.). The supplementation ponds are not part of the fish bypass facility, but are proposed as features to improve the survival quality of existing hatchery production fish.

- **Adult Fish Trap/Haul Facility Modifications**: The existing adult fish trap is located approximately two miles downstream of the Wynoochee Dam, at river mile 49.6. Modifications to the fish trap are required to improve the existing sorting and transportation process of wild fish and hatchery fish. Modifications may include changes in the sorting flume and installation of two additional holding tanks. Other modifications may include the extension of the operator’s platform to direct fish into the appropriate tanks, and the installation of new lifting devices to assist in truck loading.

- **Control Systems**: Due to its remote location, Wynoochee Dam is lightly staffed with typically only one person available for operational procedures at any given time. Therefore, there is a need to automate the control of as many aspects of this fish bypass system from the dam operations office as possible.

2.1 Intake Wetwell and Gate Shaft

There are currently two alternative points for fish to enter the Wynoochee Dam penstock. Fish can either be swept vertically down through the wetwell and directly into the penstock intake, or they can move through a temporary opening in the gateshaft that was constructed in 1997 to improve conditions for fish entry. In May and June of 1997, TPU monitored fish movement through these two openings in the intake structure. Additional monitoring of fish passage through the intake structure, once the bypass system is operational, will be conducted by TPU.

It is therefore the assumption of this report that the potential for one or both of these two points of entry to be the permanent entry to the proposed fish bypass facility will be monitored by TPU during the first few years of operation of the fish bypass system. Modifications to the intake structure that were considered at this level of design included either removal and sealing of the higher level opening or making the necessary improvements to the opening to make it a permanent feature of the fish bypass system.

2.1.1 Assumptions

- The existing trashrack on the intake structure is sufficient for trapping debris. The fish bypass system design will not include any modifications to the trashrack, nor will the design include any additional trashracks or other debris handling mechanisms.
- The existing trashrack is capable of screening debris in such a manner that will prevent a sudden and instantaneous obstruction of the Eicher screen surface.

- Once the fish bypass system is constructed and operational, TPU will monitor the bypass system for debris problems. Any modifications to the bypass system that are required to mitigate debris problems will therefore be made once the bypass system is operational. Potential debris problems could include debris loads that require unacceptably frequent backflushing of the screen or debris loads that cannot be effectively flushed from the screen surface.
- Currently, small sticks and debris pass through the existing trashrack, and it is assumed that this passed material is small enough so as not to significantly damage the Eicher screen. It is also assumed that this material, if conveyed into the bypass system, is small enough to be effectively conveyed through.
- Construction modifications to the temporary, high-level entry portal in the intake structure would occur in the dry (i.e. when the reservoir pool elevation is less than 774 feet).

2.1.2 Alternatives

Once the fish bypass system is constructed and operational, TPU will continue to monitor fish entry through the intake structure. With the additional monitoring results, the Corps, TPU, and interested resource agencies will work together to determine the optimal configuration of the intake structure for fish passage, and if the gate shaft portal is necessary. If the monitoring results indicate that the temporary intake structure modifications that were completed in 1997 are not necessary or are not beneficial for fish entry to the bypass system, then the temporary opening would be closed and sealed. If, however, it is found that the gate shaft portal is a necessary or beneficial feature for successful operation of the fish bypass system, then modifications would be made to the opening to make it permanently functional. These are the two alternatives that were considered at this stage of design for the intake structure modifications. 10% level plan drawings were not developed for this element of the project.

The first alternative proposes to permanently close and seal the high-level opening, and to dedicate the lower gate entry as the sole entry point to the penstock. Construction elements associated with this alternative include closing off the opening with concrete, removing the temporary gate and baffles, and installation of permanent attraction lighting. The preliminary cost estimate for this alternative feature is $27,600, which includes construction contingency, planning engineering and design (PED) costs, and supervisory and administrative (S&A) costs.

The second alternative proposes to modify the high-level opening so as to make it a permanent feature of the intake structure. Implementation of this alternative would allow for two permanent entry points for fish to enter the penstock. Construction elements associated with this alternative include installation of permanent hoisting equipment, baffles at both openings, and permanent attraction lighting. The preliminary cost estimate for this alternative feature is $240,000, which includes construction contingency, PED costs, and S&A costs.

2.2 Penstock Eicher Screen

An Eicher screen is a pivoting screen that is positioned within the cross-sectional area of a penstock. This screen allows water to flow through the screen to the turbines while bypassing fish bearing flows, which flow parallel to the screen surface. The use of an Eicher screen provides for continued power generation while safely bypassing fish out of the penstock. Existing Eicher screen installations have made use of a gradation of porosity so that the velocity component that is parallel to the screen is uniform along the length of the screen (Adam, Pieter et al, 1991). Additionally, by ensuring that the component of the velocity normal to the Eicher screen does not exceed 0.40 times the average penstock velocity (Criterion #9), the screen will safely guide fish along the face of the screen and into the bypass pipeline. The uniform parallel velocity and the minimal normal velocity will minimize fish impingement on the screen surface.

To incorporate an Eicher screen into the Wynoochee Dam penstock, a section of the penstock will need to be modified. The existing penstock is a spiral welded steel pipe and has a 10-foot nominal diameter. The modified penstock section is located approximately 250 feet downstream of the penstock intake, and immediately upstream of the existing air/vacuum valve assembly structure. The length of the Eicher screen is approximately 40 feet. The angle of the screen was assumed to be 16.5 degrees, which is consistent with the installation at Elwha Dam. Further analysis and refinement of the inclination angle will be conducted during the 35% design level.

Existing flow rates through the penstock range from 210 to 1300 cfs. Current design criteria (Criterion #1) specify that the Eicher screen will be used to bypass fish for penstock flows ranging from 210 cfs to 800 cfs. However, an unexpected event, such as a turbine runaway, could allow flows in the penstock to exceed 800 cfs while the Eicher screen is in operation. These excessive flows could cause damage to the Eicher screen, and subsequently could damage downstream components of the hydroelectric facility if portions of the screen were to become dislodged. Therefore, it is critical that the screen be designed to structurally withstand the fluid forces resulting from a peak flow of 1300 cfs.

2.2.1 Assumptions

- The "Eicher screen" design is the selected screen type and is the only screen type to be considered.
- The angle of inclination of the Eicher screen is set at 16.5 degrees relative to the penstock invert.
- Field-testing of full scale Eicher screen installations (Elwha Dam), and physical modeling of scaled down Eicher screen installations, have been previously conducted by others. Journal articles (Adam, Pieter et al, 1991; Winchel, Fred C. et al, 1991) summarizing some of the results of these tests are included in Appendix H. The results of these tests determined an Eicher screen configuration that appeared to be most effective in sweeping migrating fish from a penstock into a pressurized bypass pipeline. Therefore, it is assumed for the 10% level of design that the Eicher screen installation at Wynoochee Dam will be similar to the successful installation at Elwha Dam.
- Current design criteria (Criterion #1) specify that the Eicher screen will operate with flows ranging between 210 cfs and 800 cfs. However, the structural design of the screen must accommodate flows as high as 1,300 cfs.

- During non-migration periods the screen will not be located within the normal flow stream. Depending on the alternative, turbine flow will either be diverted through a penstock bypass section (Alternatives 1 and 2) or the Eicher screen penstock section will be removed (Alternative 3). This will prolong the screen life, reduce the risk of screen component failures and subsequent downstream damage, and reduce the risk of damage due to debris within the flow stream.
- The screen will be actuated to rotate approximately 20 degrees to allow stream flow to enter the screen from the underside so as to backflush collected debris off the surface.
- All structural and foundation elements of the modified penstock section will be designed for seismic zone 3, as defined in the Uniform Building Code.
- Depth to bedrock in the vicinity of the Eicher screen penstock section is 3 to 5 feet below existing ground surface. It is further assumed that the underlying bedrock is weathered and can be excavated to an approximately vertical surface with an excavator.
- Lateral earth pressure due to the upper five feet of the soil column will exert a uniform pressure of 75 psf, which includes an allowance for equipment surcharge.
- It is assumed that flow through the penstock can be shutdown for several consecutive days to allow for switching between modes of operation (e.g. screened versus non-screened).
- Pressure sensors will be installed upstream and downstream of the Eicher screen to detect increases in pressure differential caused by debris obstruction on the screen. The pressure differential that will initiate the backflushing of the screen is assumed to be 2 feet greater than that associated with an unobstructed screen.
- Backflushing of the screen will also occur at regularly scheduled intervals in addition to when the allowable pressure differential is exceeded.
- The penstock has pressure sensors at the intake and at the air/vacuum valve assembly structure that is located just upstream of USFS Road 2294. Additional pressure sensors would be required in the penstock, both upstream and downstream of the Eicher screen to monitor the pressure differential across the screen.

- Wynoochee Dam operates on a flow (cfs) control system rather than a megawatt control system. Therefore, it will be necessary to include in the design the ability to measure the flow rate in the penstock, upstream of the bypass, and within the bypass pipe itself.

2.2.2 Alternatives

Two fundamentally different operational approaches were considered for incorporating the ability to include an Eicher screen operation into the existing penstock. The first operational approach involves installing the Eicher screen in a fixed section of the existing penstock and constructing a permanent bypass penstock section around the Eicher screen. The second operational approach involves installing the Eicher screen in a replaceable section of penstock, which would be removed during the non-fish passage window and replaced with a penstock section without an Eicher screen.

Using the two operational approaches, a total of three Eicher screen alternatives were developed – two using the parallel pipe bypass approach and one using the removable Eicher screen section approach. The three alternatives are described in the following sections.

2.2.2.1 Eicher Screen Alternative 1

Alternative 1 proposes to install the Eicher screen in the existing penstock section, approximately 100 feet upstream of the existing air/vacuum valve assembly structure (refer to Figure 1). A permanent 10-foot diameter bypass penstock section, approximately 150 feet in length, would be constructed parallel to the Eicher screen section (Refer to Plan Sheets 4 and 15). Specially fabricated lateral “Y” penstock sections would connect the bypass penstock section to the existing penstock section. It will be necessary that the lateral “Y” penstock section be designed and fabricated to provide a smooth continuous interior surface. It is proposed that a knife gate valve be used in this alternative to close flow to the Eicher screen section of penstock and divert the flow to the bypass section during non-migration periods. During migration periods, the knife gate valve would be opened, and a specially fabricated fiberglass or steel plug would be installed in the upstream lateral "Y" to provide a smooth inner pipe surface to eliminate any stagnant flow area in the vicinity of the lateral "Y". A 10 foot long, removable pipe section would be designed to allow for the installation and removal of the specially fabricated plug. Blind flanges would be installed in the bypass section during screening periods to retain the plug and to prevent backflow through the downstream lateral "Y" section.

Figure 1. Proposed Location of Eicher Screen Section.
The existing air/vacuum valve structure is seen in the background, as is USFS Road 2294.

To provide easy access to all components of the system, a below grade vault approximately 150-feet long and 45-feet wide would be constructed to contain the bypass penstock pipe and Eicher screen section.

The preliminary cost estimate for this alternative feature is $3,323,900, which includes construction contingency, PED costs, and S&A costs. Refer to Plan Sheet 4 (Appendix C) for plan/profile of this alternative and Plan Sheet 15 (Appendix C) for details and sections of this alternative.

Advantages associated with this alternative include:

- The penstock flow only needs to be shutdown long enough to open or close the knife gate valve and to insert or remove the specially fabricated plug. The duration of the shutdown period will be shorter than required for Alternative 3.
- All piping can maintain a circular cross section thus utilizing standard pipe materials.
- Using lateral "Y" sections and 45 degree bends minimizes head loss in the bypass penstock section.
- The Eicher screen would not be located within the flow stream during the non-migration period.
- The Eicher screen would be located within a straight section of the penstock, approximately 200 feet downstream of an existing bend, thereby allowing for the flow to fully develop prior to encountering the screen.

Disadvantages associated with this alternative include the following:

- The knife gate valve is very large and expensive.
- The knife gate valve does not provide smooth flow stream surfaces.
- The 10-foot diameter plugs and blind flanges must be installed and uninstalled each time the penstock bypass is taken on or off line.
- The Eicher screen cannot be isolated for maintenance during periods of power generation. Hydroelectric generation must be temporarily shut down to allow for dewatering of the Eicher screen section and to allow access to the Eicher screen for maintenance. Installation of a second knife gate would, however, allow for isolation of the Eicher screen during periods of power generation.

2.2.2.2 Eicher Screen Alternative 2

Alternative 2 is similar to Alternative 1 in that the Eicher screen is proposed to be installed in the existing penstock, approximately 100 feet upstream of the existing air/vacuum valve assembly structure (refer to Figure 1). A permanent 10-foot diameter penstock section, approximately 150 feet in length, would be constructed parallel to the Eicher screen section (Refer to Plan Sheets 5 and 16). The difference between the two alternatives is that a swing gate is used to direct flow into either of the two parallel penstock sections. The custom-designed swing gate would be motor actuated and operated only under de-watered, no flow conditions. A lateral “Y” section would be fabricated with a square cross section along with circular transitional sections to accommodate the swing gate. The swing gate is designed to provide smooth contact areas and surfaces. During the migration window, flow is directed through the Eicher screen. The screen is located in the “straight through” flow stream to minimize transitional turbulence typically created downstream of bends. During non-migration periods, the swing gate directs the flow through the bypass penstock section, thus bypassing the Eicher screen section.

To provide for easy access to all components of the system, two below grade vaults would be constructed to contain the bypass penstock pipe and Eicher screen section.

The preliminary cost estimate for this alternative feature is $2,279,800, which includes construction contingency, PED costs, and S&A costs. Refer to Plan Sheet 5 (Appendix C) for plan/profile of this alternative and Plan Sheet 16 (Appendix C) for details and sections of this alternative.

Advantages associated with this alternative include:

- Penstock flow only needs to be shut down long enough to change position of the swing gate. The shut down period for this alternative will likely be less than that required for either Alternative 1 or Alternative 3.
- A specially fabricated plug is not needed, and no removable pipe sections are needed.
- Head loss in the bypass penstock section is minimized by using laterals and 45 degree bends.
- The Eicher screen would not be located within the flow stream during the non-migration period.

- The Eicher screen would be located within a straight section of the penstock, approximately 200 feet downstream of an existing bend, thereby allowing for the flow to fully develop prior to encountering the screen.
- The swing gate is significantly less expensive than the knife gate
- The swing gate provides smooth interior surfaces.
- Changeover can be done in relatively short time.
- Cross section shapes are maintained because no pipe sections need to be removed and stored.

Disadvantages associated with this alternative include the following:

- Upstream lateral "Y" section needs to be fabricated to provide square cross section to accommodate the swing gate.
- Swing gate will need to be custom-designed and fabricated.
- Swing gate seal may not be 100% watertight.
- Eicher screen cannot be isolated for maintenance while penstock is in use. Hydroelectric generation must be temporarily shut down to allow for dewatering of the Eicher screen section and to allow access to the Eicher screen for maintenance.

2.2.2.3 Eicher Screen Alternative 3

Alternative 3 proposes constructing the Eicher screen within a 50-foot section of penstock that could be removed and replaced (refer to Plan Sheets 6 and 17). The modified penstock section containing the Eicher screen would be interchanged with a regular section of penstock. Such an interchange would be expected to occur during times of non-fish screening or during periods of screen maintenance and repair. Prior to switching the sections, the penstock would have to be dewatered. For interchangeable ease, each section would be mounted on a rail system oriented perpendicular to the penstock. This rail system would be bolted to the floor of a concrete vault that is cast between the two ends of the penstock. This rail system would allow the sections to be rolled in and out of alignment with the penstock.

To provide for easy access to all components of the system, a below grade vault approximately 74 feet long and 45 feet wide would be constructed to contain the two penstock sections and the rail system that would be used to move the sections in and out of position.

The preliminary cost estimate for this alternative feature is $1,583,100, which includes construction contingency, PED costs, and S&A costs. Refer to Plan Sheet 6 (Appendix C) for plan/profile of this alternative and Plan Sheet 17 (Appendix C) for details and sections of this alternative

Advantages associated with this option include the following:

- Straight through flow is maintained in both configurations, i.e. when screening is needed and when screening is not needed.
- All piping can maintain a circular cross section thus utilizing standard pipe materials.
- Alternative 3 requires a single, smaller below grade vault as compared to the other two alternatives.
- By allowing for the removal of the Eicher screen pipe section, the maintenance of the screen can be conducted while the penstock is in operation
- Alternative 3 is the cheapest of the three Eicher screen alternatives.

Disadvantages associated with this option include the following:

- The system must be shut down for an extended period of time to allow for the manual removal and replacement of the pipe sections. It is estimated that the required shut down time would be roughly two to three days.
- Significant labor is required for switching the pipe sections.
- A fairly elaborate rail system and motorized mechanical system will be required due to the weight of the penstock sections.
- Maintaining an accurate circular cross section for the “standby” pipe section would require significant stiffening or internal bracing.
- Connection and disconnection of the 24-inch pressure bypass pipeline would be required when the penstock sections are moved.

2.3 Pressure Bypass Pipe

The pressure bypass pipe would connect to the crown of the penstock, immediately upstream and above the proposed Eicher screen. The bypass pipe would convey fish bearing bypass flows from the west side to the east side of the Wynoochee River. The crossing of the river would be accomplished by suspending the pressure bypass pipeline beneath the existing USFS Road 2294 bridge structure. The pressure bypass pipe would discharge into the next downstream component of the bypass system, the proposed multi-level discharge system.

The hydraulics of the bypass system would be designed such that the flow velocities would accelerate as flows are conveyed along the face of the screen and into the pressure bypass pipeline. Once entry is made into the pressure pipeline, the average flow velocity throughout the remainder of the pressure bypass system would remain moderate and uniform, with magnitudes ranging between 7 fps and 10 fps (Criterion #5 and #11). The magnitude of the actual velocity through the bypass pipeline will be dependent on the reservoir pool elevation and the flow rate through the penstock upstream of the Eicher screen. The velocity criteria, and how they apply to the pressurized bypass pipeline, are discussed in more detail in the multi-level flume system section of this report.

Flow through the bypass pipe will range from 10 cfs to 30 cfs (Criterion #10), which is about 2 - 5 % of the maximum expected penstock flow during the fish passage window. This flow rate range will be maintained for varying reservoir pool elevations through the use of a multi-level discharge system, which is described in a later section of this report.

The pressurized bypass pipe will be 24 inches in diameter to prevent debris jams, facilitate operation and maintenance, and to protect fish from injury (Criterion #7). To minimize damage to fish, considerations will be given for wall smoothness and joints. The bend radii will be limited to no less than five times the pipe diameter (e.g. 10 foot radius for a 24-inch diameter pipe), and the magnitude of the bypass velocities will be within the stated criteria. To meet these criteria, the bypass pipeline will be constructed of 24-inch diameter high-density polyethylene (HDPE) pipe.

2.3.1 Assumptions

- The bypass pipeline will be 24-inches in diameter.
- Design flow rates through the pressure bypass pipeline will range between 10 and 30 cfs. The possibility for flow surges in excess of the bypass pipe design flow rate, caused by a sudden and instantaneous obstruction of the screen, or caused by the backflushing of the screen, was not considered at this level of design.
- To make the crossing of the Wynoochee River, the HDPE pipe will be supported in a steel casing, which will be attached to the USFS Road 2294 bridge structure.
- It is assumed that the existing bridge structure is capable of supporting the additional 45,000 pounds of load, due a full 24-inch diameter pipe. The load will be distributed over supports at approximately 10-foot spacing. Additional structural analysis of the bridge structure should be considered at the 35% level of design.
- The HDPE bends will be constructed of mitered tangent sections of pipe.
- All HDPE pipe sections will have inside butt fusion beads removed at the joints.
- Minimum allowable bend radius will be 5 times the pipe diameter (e.g. 10 foot radius for a 24-inch diameter pipe).
- The system must meet all other applicable design criteria as listed in Appendix A.

2.3.2 Alternatives

No alternatives were identified for the pipeline alignment nor for the concept of attaching it to the USFS bridge. Therefore, only a single alignment alternative is presented. The pipeline alignment is shown on Plan Sheet 7 in Appendix C. As seen in the drawing approximately 250 linear feet of the bypass pipeline is proposed to be suspended under the existing USFS Road 2294 bridge structure. The HDPE pipe is proposed to be installed within a 36-inch diameter steel casing pipe, which will be attached to the bridge structure with trapeze and bracing. The HDPE pipe will be free to move inside the casing, thereby accommodating thermal expansion and contraction. Lateral movement due to thermal expansion and contraction along the remainder of the alignment will be minimized by directly burying the pipe. Expansion joints will be provided for the above grade sections of the pipe, to allow for expansion and contraction without damaging the pipe material or the joints. The design criteria that limits bends in the pressure pipe to five pipe diameters or greater will force the alignment away from the bridge on both sides.

Sensors will be included within the pressure bypass pipeline that will relay the pressure of the bypassed flow to the control center. A set of valves, or a single valve, will be included in the pressure bypass system to allow for dewatering of the pressure pipe when it is not being used or when it needs to be shut down to make adjustments to the discharge system. Access ports in the pressure pipe would be included at two locations – upstream of the multi-level discharge system and upstream of the bridge crossing.

The preliminary cost estimate for this alternative feature is $366,600, which includes construction contingency, PED costs, and S&A costs. Refer to Plan Sheet 7 in Appendix C for the plan and profile of this alternative.

Advantages associated with this alternative are as follows:

- The high-density polyethylene (HDPE) pipe is very smooth and durable.

Disadvantages associated with this alternative are as follows:

- HDPE pipe is highly susceptible to thermal expansion and contraction when constructed above grade.
- All horizontal bends in the pipeline alignment will need to be constructed from mitered tangent sections. However, all interior beads will be removed to provide a smooth interior surface.
- Care must be taken at transitions to steel pipe to assure inside diameters match.

2.4 Multi-Level Discharge System

The need to operate the fish bypass facility for varying reservoir pool elevations and varying penstock flow rates requires the development of a project feature that will provide operational flexibility during these changing conditions. At the terminus of the pressure bypass pipe, prior to discharge to the gravity flume, a multi-level discharge system is proposed. This system is comprised of multiple pressure outlet pipes that will discharge into the gravity flume at specific, fixed elevations. The multi-level discharge system will allow for the pressure bypass pipeline, as described in the previous section, to be connected to any one of a number of pressure outlet pipes. The decision as to which outlet pipe to connect to will depend upon the reservoir pool elevation and the penstock flow rate at the time of operation.

Assuming an initial reservoir pool level of 800 feet, and assuming the reservoir pool level decreases during the fish migration window, the multi-level discharge system would operate as follows. Within the fish bypass window, the outlet pipe that connects to the highest point of the gravity flume would be capable of conveying 35 cfs (the maximum allowable bypass flow rate) when the penstock is flowing at the maximum anticipated penstock flow and when the reservoir pool elevation is at 800 feet (the maximum reservoir pool elevation). As the reservoir pool level decreases, and assuming the penstock flow remains constant, the resulting flow rate that would be capable of being conveyed through the pressurized bypass system would also decrease, due to the decrease in available upstream head. At some point, when the reservoir pool elevation has decreased enough, the flow rate through the bypass pipeline would begin to approach the lower allowable limit of 20 cfs. At this point, it would be necessary to connect the pressure bypass pipeline to the next lowest of the outlet pipes in the multi-level discharge system. This would increase the head differential within the pressure system and allow for a higher magnitude bypass flow to enter the bypass system. As the reservoir pool level continues to decrease, it would at some point become necessary to switch to the next lowest of the outlet pipes. This process would continue as the reservoir pool level continued to decrease. If the reservoir pool elevations were to increase, then the procedure would occur in reverse, with higher elevation outlet pipes being connected. The downstream-most outlet pipe would be designed to convey the minimum bypass flow rate (20 cfs) at the minimum reservoir pool elevation (760 feet). A more detailed discussion of the operation of the multi-level discharge system and the hydraulic analysis of the system is provided in Appendix B.

2.4.1 Assumptions

- During the fish migration window, the reservoir pool elevation will vary between 760 feet (mean sea level) and 800 feet (mean sea level). The 800-foot reservoir pool elevation is associated with full conditions in the reservoir, and the 760-foot elevation is associated with the minimum operating level for the hydroelectric facility.
- During the fish migration window, it is assumed that the minimum flow rate through the penstock will be 210 cfs, and that TPU will be capable of limiting the maximum flow rate through the penstock to no more than 600 cfs, which violates Criterion #1. The hydraulic analysis of the pressurized pipe system and the multi-level discharge system concluded that a prohibitively large number of outlet pipes would be required to allow the bypass system to operate with an 800 cfs penstock flow rate.
- The configuration of the multi-level discharge system must allow for the conveyance of between 10 and 30 cfs for the range of reservoir pool elevations and penstock flows identified above.
- The multi-level discharge system must be capable of ensuring that the average velocity in the pressure bypass pipeline is greater than the average penstock velocity for all operating conditions.
- Vehicle access to the area of the proposed multi-level discharge system is limited, and therefore, systems need to be designed for maintenance and operation using minimal amounts of mobile equipment.
- The existing paved trail at the site of the proposed multi-level discharge system (refer to Figures 2 and 3) can be relocated to the west if necessary.
- The existing water level monitoring wells located at the downstream face of the dam fill can be abandoned or relocated if required.
- Construction of the multi-level discharge system must not impact previously identified trees of significance.
- In general, the forested area on the east side of the existing paved trail needs to be preserved with minimal to no tree removal.

- The discharge transitions from the pressure pipeline to the gravity flume will need to be designed to prevent injury to fish.
- The multi-level discharge system must meet all other applicable design criteria as listed in Appendix A.

2.4.2 Alternatives

Two multi-level discharge system alternatives were developed and analyzed and are described in detail in the following sections. The number of outlets that are required and the invert elevation of each outlet are specific to each alternative, and are presented in detail in the following sections. A detailed discussion of the operation of the multi-level discharge system and the hydraulic analysis of the system is provided in Appendix B.

2.4.2.1 Multi-Level Discharge System Alternative 1

Alternative 1 proposes the construction of a below grade pipe selection facility and a bank of six, 24-inch diameter, HDPE pressure pipes, each leading to a specific outlet elevation at the gravity flume. Refer to Plan Sheet 8 (Appendix C) for a plan view of this alternative and Plan Sheet 18 (Appendix C) for details and sections of this alternative. The proposed pipe selection facility vault is located on the downstream end of the bypass pressure pipeline and consists of a specially fabricated U-shaped pipe segment that would be capable of rotating and connecting to one of six pipelines, each leading to a specific outlet elevation at the gravity flume. The U-shaped pipe would be fabricated with steel or with HDPE, depending on cost considerations and constructability. All the piping downstream of the discharge vault that is currently active, including the pipe within the vault, will need to be dewatered each time the discharge pipe is switched. As seen in Plan Sheet 8 (Appendix C) each of the six discharge pipes will be connected to a 180-degree, U-shaped pipe section, the outlet of which will be aligned parallel to the gravity flume.

The hydraulic analysis of the pressure bypass system and the Alternative 1 configuration of the multi-level discharge system determined that six outlet pipes would be required to allow the bypass system to operate throughout the range of reservoir pool elevations and penstock flow rates expected during the fish passage window. This same analysis was used to determine the required outlet elevations for each outlet pipe and the operating curve for each outlet pipe. During the 35% design phase, considerations should be given to investigating cost effective means to possibly reduce the number of required outlet pipes. It may be possible to reduce the required number of outlet pipes by either reducing the maximum penstock flow rate that is allowed during the fish passage window (thereby reducing the average velocity through the penstock), or by increasing the head losses through the pressurized bypass system. There are cost and operational trade-offs associated with these two decisions, and it is therefore assumed they be considered during the development of the 35% design.

Table 1 summarizes the computed invert elevations of the six outlet pipes, and the range of reservoir pool elevations that each outlet pipe would operate within. The range of reservoir pool elevations shown in Table 1 represent the operating range of each outlet pipe assuming a 600 cfs penstock flow rate. The operational ranges would be slightly wider for penstock flow rates less than 600 cfs, since the allowable velocity in the bypass is dependent on the average penstock velocity. Refer to the hydraulic appendix (Appendix B) for the complete set of operating curves for the outlet pipes in Alternative 1.

Table 1. Multi-Level Outlet Elevations for Alternative 1

Outlet Pipe #	Invert Elevation of Outlet Pipe (feet)	Lower Limit of Reservoir Pool (feet) (Q_{bypass} = 23 cfs)	Upper Limit of Reservoir Pool (feet) (Q_{bypass} = 35 cfs)
1	783.4	791.4	800.0
2	776.9	784.2	791.9
3	770.4	777.4	784.7
4	764.2	770.9	777.9
5	758.3	764.8	771.4
6	752.7	759.0	765.3

Outlet pipe #6 is required so as to allow the bypass system to operate when the reservoir pool is at the minimum operating elevation of 760 feet. Therefore the 752.7 foot invert elevation of this outlet pipe is the lowest of the six outlet pipes. As seen in Plan Sheets 8 and 10, ground elevations along the flume alignment upstream of USFS Road 2294 may require the flume to be constructed five feet lower from what is currently proposed. This will result in a flume alignment that is up to six feet below existing grade. The results of the topographic survey that will be conducted during the 35% design phase, and the refinement of the hydraulic analysis that will be conducted during the 35% design phase, will be used as tools to minimize the depth of the flume alignment upstream of the USFS Road.

The existing paved trail would need to be relocated to the west to accommodate the 25-foot by 50-foot below grade vault that would house the pipe selection facility. To accommodate the bank of 24-inch pipelines, some trees located to the west of the existing trail would likely need to be removed, and several existing ground water monitoring wells located on the downstream face of the dam would have to be abandoned.

The preliminary cost estimate for this alternative feature is $1,560,700, which includes construction contingency, PED costs, and S&A costs. Refer to Plan Sheet 8 (Appendix C) for plan and profile of this alternative and Plan Sheet 18 (Appendix C) for details and sections of this alternative.

Advantages associated with this alternative include the following:

- Switching between outlet pipes will occur in one location.
- The pipe selection vault is located close to USFS Road 2294 and the dam access road, which would thereby enable heavy equipment to access the facility for maintenance.
- During switching operations, fish sampling could occur when water is drained out of the previously active discharge pipe.
- The pipe selection switching system can be operated manually, with the use of non-motorized mechanical equipment.

Disadvantages associated with this alternative include the following:

- The pressure bypass system must be dewatered at the pipe selection vault each time a new discharge outlet pipe is connected.
- A large below grade vault is required to house the pipe distribution system. Safety provisions would be required to prevent injury to operations staff in the event that an upstream valve fails or is inadvertently opened.
- All of the fish that are in the previously active multi-level pipeline will be drained from the system and discharged to the river via the drain system. This drain system will have significant drop to the river below, likely resulting in fish mortality.

2.4.2.2 Multi-Level Discharge System Alternative 2

Alternative 2 consists of extending the single, 24-inch diameter bypass pressure pipeline further up the existing paved trail, all the way to the head of the gravity flume. The bypass pressure pipeline will be constructed to attach to multiple removable U-shaped pipe sections. In order to connect the bypass pressure pipeline to a specific U-shaped pipe section, a ball valve would be closed and the bypass pressure pipeline downstream of the next U-shaped pipe section would be dewatered. The removable pipe section would then be disconnected and manually moved out of place. The U-shaped pipe section would be manually moved into place and connected to the pressure pipeline. The outlet of the U-shaped pipe section would be lowered flush with the gravity flume. The ball valve would then be opened and the bypass system would continue to operate. A detail of the multi-level discharge system Alternative 2 is shown on Plan Sheet 9 and Plan Sheet 19 in Appendix C.

The hydraulic analysis of the pressure bypass system and the Alternative 2 configuration of the multi-level discharge system determined that seven outlet pipes would be required to allow the bypass system to operate throughout the complete range of reservoir pool elevations and penstock flow rates expected during the fish passage window. This same analysis was used to determine the required outlet elevations for each outlet pipe and the operating curve for each outlet pipe. During the 35% design phase, considerations should be given to investigating cost effective means to possibly reduce the number of required outlets. It may be possible to reduce the required number of outlets by either reducing the maximum allowable penstock flow rate during the fish passage window (thereby reducing the average velocity through the penstock), or by increasing the head losses through the pressure pipe system. There are cost and operational trade-offs associated with these two decisions, and it is therefore assumed they be considered during the 35% design phase.

Alternative 2 requires one more outlet pipe than Alternative 1 due to the fact that there is slightly less head loss in the multi-level discharge system configuration under Alternative 2 than under Alternative 1. This smaller amount of head loss results in a smaller range of reservoir levels that a specific outlet pipe can remain in operation before it is necessary to switch to the next outlet pipe.

Table 2 summarizes the computed invert elevations of the seven outlet pipes, and the range of reservoir pool elevations that each outlet pipe would operate within. The range of reservoir pool elevations shown in Table 2 represent the operating range of each outlet pipe assuming a 600 cfs penstock flow rate. The operational ranges would be slightly wider for penstock flow rates less than 600 cfs, since the allowable velocity in the bypass is dependent on the average penstock velocity. Refer to the hydraulic appendix (Appendix B) for the complete set of operating curves for the outlet pipes in Alternative 2.

Table 2. Multi-Level Outlet Elevations for Alternative 2

Outlet Pipe #	Invert Elevation of Outlet Pipe (feet)	Lower Limit of Reservoir Pool (feet) (Q_{bypass} = 23 cfs)	Upper Limit of Reservoir Pool (feet) (Q_{bypass} = 35 cfs)
1	784.8	792.2	800.00
2	779.2	785.9	792.7
3	773.5	779.9	786.4
4	768.1	774.2	780.4
5	763.1	769.0	774.7
6	758.3	764.0	769.5
7	753.3	759.0	764.5

Outlet pipe #7 is required so as to allow the bypass system to operate when the reservoir pool is at the minimum operating elevation of 760 feet. Therefore the 753.3 foot invert elevation of this outlet pipe is the lowest of the six outlet pipes. As seen in Plan Sheets 9 and 10, ground elevations along the flume alignment upstream of USFS Road 2294 may require the flume to be constructed five feet lower from what is currently proposed. This will result in a flume alignment that is up to six feet below existing grade. The results of the topographic survey that will be conducted during the 35% design phase, and the refinement of the hydraulic analysis that will be conducted during the 35% design phase, will be used as tools to minimize the depth of the flume alignment upstream of the USFS Road.

Depending on the final vertical alignment of the flume, some of the crane support structures may need to be constructed within below grade vaults.

Similar to Alternative 1, the existing paved trail would need to be relocated to the west to accommodate the seven U-shaped pipe sections and the six crane support structures. Additionally, some trees located to the west of the existing trail would likely need to be removed, and several existing ground water monitoring wells located on the downstream face of the dam would have to be abandoned.

The preliminary cost estimate for this alternative feature is $1,116,100, which includes construction contingency, PED costs, and S&A costs. Refer to Plan Sheet 9 (Appendix C) for plan and profile of this alternative and Plan Sheet 19 (Appendix C) for details and sections of this alternative.

Advantages associated with this alternative include the following:

- Only one pipeline would be constructed along the alignment of the existing paved trail, therefore resulting in a narrower project footprint along the trail.
- Only that portion of the pressure pipe that is located downstream of the new discharge point will need to be dewatered during switch over, thus resulting in

less dewatering than Alternative 1. Likewise, during switch over, fewer fish would be trapped in the system as compared to Alternative 1.

- The outlet of the U-shaped sweep segment will be capable of being raised and lowered, thus allowing the active pipe to be set flush with the gravity flume invert and allow for a smoother transition into the flume. When a specific U-shaped sweep is not actively conveying bypass flows, it can be raised high enough above the gravity flume invert so as to be clear of the flow in the flume.
- The Alternative 2 multi-level discharge system is less expensive than the Alternative 1 multi-level discharge system.
- The pipe selection switching system can be operated manually, with the use of non-motorized mechanical equipment.

Disadvantages associated with this alternative include the following:

- Switching out the U-shaped sweep segments and the replaceable pipe segments will likely require significant manual operations.
- Some of the crane system structures would be constructed above grade, and will be considerably more intrusive than the below grade multi-level discharge concept presented as Alternative 1.
- The construction of the crane systems and the U-shaped sweep segments proposed as part of Alternative 2 will require more surface grading and excavation than is required under Alternative 1. Each crane system structure will have to be constructed on a fairly level, 15-foot by 35-foot pad.

2.5 Gravity Flume

A gravity flume element is required to convey the fish and the bypass flows from the outlet of the pressurized multi-level discharge system to the transitional ponds. The gravity flume will be approximately 1,550 feet in length, as measured from the most upstream multi-level outlet pipe to the transitional pond, and will drop approximately 120 vertical feet. The proposed alignment of the flume will follow the east side of the paved powerhouse access road, at the toe of an existing embankment. For a majority of the alignment, the flume will be constructed near existing grade, and therefore will follow the existing topography. The slope of the flume will vary between 2.7% and 14.1%. Because of the steep slope at the upstream end of the alignment (approximately 6%), the range of flows that will be discharged from the pressurized system into the flume will assume a supercritical flow regime. One of the design criteria requires that no hydraulic jumps be allowed within the flume system, and therefore, supercritical flow must be maintained along the entire length of the alignment. Plan Sheets 10, 11, 12, and 13 show the plan and profile of the proposed gravity flume. Photographs of the gravity flume alignment are included in this report as Figures 2 through 6.

Two reaches of the flume will be constructed below grade, for a total length of approximately 400 feet. In the upper portion of the flume, a 150 linear foot segment would be constructed below grade so as to cross underneath the existing USFS Road 2294. Through this reach, the invert elevation of the flume is proposed approximately eight feet below the existing grade of the road. At the downstream end of the flume, approximately 250 linear feet, would be constructed at or slightly below grade so as to accommodate existing topography and to allow for the crossing of the existing substation access road that is located immediately upstream of the transition ponds. All above grade and near grade flume sections will be constructed with a screen cover to prevent limbs and leaves from falling into the flow, to minimize the possibility for vandalism, and to provide for visual inspection of fish.

There is an existing underground drainage system along the alignment of the flume, downstream of the USFS road crossing. Existing underground electrical conduits and a 30” x 77” CMP culvert in the vicinity of Station 23+00 (see Plan Sheet 13) will also limit the allowable depth of excavation for the gravity flume. According to Wynoochee Dam Hydroelectric Project Record Drawings (City of Tacoma, 1991), the invert elevation of the CMP culvert is approximately 664.9 feet where the flume alignment crosses, which is approximately five feet below existing grade. There is therefore 2.5 feet of cover over the CMP culvert. The record drawings also indicate that the electrical conduits are buried with a minimum of 18-inches of cover. At this time, it is unknown whether the conduits are buried above or below the culvert.

To minimize injury and stress to fish as they are conveyed through the flume, the depth of flow in the flume cannot be less than 9 inches (Criterion #14) and velocities cannot exceed 35 fps (Criterion #12). Normal flow depths, average velocities, and Froude numbers were determined for the anticipated range of flow rates and flume gradients to verify that supercritical flow would be maintained throughout the alignment. Additionally, the phenomenon of water surface superelevation was also considered in the open channel analysis. The minimum allowable radius of curvature for each flow rate and gradient was determined that would still allow for the required 12 inches of freeboard. The results of the open channel analysis, as presented in Table 3, were used to develop the vertical and the horizontal gravity flume alignments. A more detailed discussion of the hydraulic analysis of the gravity flume is included in Appendix B.

Table 3. Hydraulic Parameters for Gravity Flume

	20 cfs Open Channel Flow Rate					35 cfs Open Channel Flow Rate				
Slope (ft/ft)	**Flow Depth (ft)**	**Hydraulic Depth (ft)**	**Average Velocity (fps)**	**Froude No.**	**Minimum Radius* (ft)**	**Flow Depth (ft)**	**Hydraulic Depth (ft)**	**Average Velocity (fps)**	**Froude No.**	**Minimum Radius* (ft)**
0.005	2.03	1.38	7.28	1.09	N.A	2.81	2.17	8.13	0.97	N.A
0.01	1.69	1.14	9.55	1.58	17	2.28	1.63	10.77	1.49	N.A
0.02	1.40	0.97	12.54	2.25	13	1.89	1.26	14.14	2.22	N.A
0.03	1.26	0.88	14.70	2.77	14	1.70	1.15	16.58	2.73	52
0.04	1.16	0.82	16.45	3.21	15	1.57	1.07	18.56	3.16	44
0.05	1.09	0.77	17.95	3.60	16	1.48	1.02	20.26	3.54	42
0.06	1.04	0.74	19.27	3.96	17	1.41	0.98	21.77	3.89	41
0.07	0.99	0.71	20.46	4.29	18	1.35	0.93	23.12	4.21	41
0.08	0.96	0.68	21.56	4.60	19	1.30	0.91	24.36	4.51	42
0.09	0.93	0.66	22.56	4.88	20	1.26	0.88	25.52	4.79	43
0.10	0.90	0.64	23.50	5.16	21	1.23	0.86	26.59	5.06	44
0.11	0.88	0.63	24.39	5.42	21	1.20	0.84	27.60	5.32	45
0.12	0.86	0.61	25.22	5.67	22	1.17	0.83	28.56	5.56	46
0.13	0.84	0.60	26.02	5.91	23	1.14	0.80	29.46	5.79	46
0.14	0.82	0.59	26.77	6.14	24	1.12	0.79	30.33	6.02	47
0.15	0.80	0.58	27.49	6.37	25	1.10	0.77	31.16	6.24	49
0.16	0.79	0.57	28.18	6.59	26	1.08	0.76	31.95	6.45	50
0.17	0.78	0.56	28.85	6.80	26	1.06	0.75	32.72	6.66	50
0.18	0.77	0.55	29.49	7.00	27	1.04	0.74	33.46	6.85	51
0.19	0.75	0.54	30.11	7.20	28	1.03	0.73	34.17	7.05	52

* Minimum radius is the required radius of bend to maintain 12-inches of freeboard, including the effect of superelevation

2.5.1 Assumptions

- Including the estimated effect of superelevation, a minimum of 12-inches of freeboard will be maintained in the flume for the 35 cfs flow rate.
- The maximum allowable velocity through the flume section is 35 feet per second
- Horizontal and vertical curves in the flume alignment must have at least a 60-foot radius (Criterion #15).
- Hydraulic jumps are not allowed within the flume alignment, and hence, supercritical flow must be maintained in the alignment for all operating conditions (Criterion #13).
- Hydraulic jumps are only allowed at the point where the gravity flume discharges to the river or to the transitional ponds.
- Flume foundations must accommodate the existing subsurface drainage system that is located on the east side of the existing powerhouse access road.
- The flume must not block hillside surface and subsurface drainage.
- The existing powerhouse access road width must remain unchanged.
- Neither roadway nor hillside drainage can be allowed to enter the flume.
- If the flume is constructed below grade adjacent to the powerhouse access road, it will need to be designed as a retaining structure that allows for the collection and conveyance of the hillside surface water.
- The horizontal and vertical alignment of the substation access road at the downstream end of the flume shall remain as existing. In the event that it is necessary to modify the vertical profile of the road to accommodate the below grade crossing of the flume, the modifications must be designed to allow continued use of the road by lowboy trailers that are used to service the transformers at the substation.
- The existing trashrack on the intake structure is capable of preventing a sudden and instantaneous obstruction of the Eicher screen. Such an obstruction could result in a flow surge through the bypass system, which would result in overtopping of the flume and undermining of the substation access road.

- The design of the gravity flume must adhere to all other pertinent design criteria as identified in Appendix A.

2.5.2 Alternatives

Four gravity flume alternatives were considered for this Interim Design Report. Three of the alternatives assumed an identical horizontal and vertical alignment, and differed only in the material used for the flume construction. The flume cross section was assumed to be the same for the three alternatives, and is shown on Plan Sheet 21 in Appendix C. The plan and profile of the gravity flume is shown in Plan Sheets 10,11,12, and 13.

A fourth alternative was conceptually analyzed as an alternative to the entire gravity flume concept. This fourth alternative considered the possibility of eliminating the multi-level discharge system and the gravity flume system, and instead, extending the pressure bypass pipeline all the way to the transitional ponds. To replace the required operational flexibility that the multi-level discharge system provided, pinch valves were proposed to be installed incrementally along the alignment of the extended pressure bypass pipeline to control the flow through the system.

2.5.2.1 Gravity Flume Alternative 1

Alternative 1 is a precast concrete flume, which would be constructed of 20 to 40-foot long precast concrete segments that are joined in the field. The interior surface of the flume would be lined with a polyurea coating system to provide for a smooth surface that would minimize injury to fish. The polyurea system consists of a two component elastomeric compound. Each component is heated and applied to the concrete surface at high pressure. A high modulus product with an elongation capability of 650% or greater will be used. This material has been tested to be compatible with fish, using Washington State Department of Ecology Static Acute Toxicity Test. Joints in the precast flume will be filled with high density foam. A flexible silicon sealant and the polyurea liner will also be field applied to allow the joint to continue to move without being damaged.

Surface and subsurface flows emanating from the adjacent hillside will be accommodated by providing a perforated drain line on the uphill side of the flume. The drain will be connected to the existing stormwater conveyance system that parallels much of the access road. During 35% design, it will need to be verified that the existing stormwater system has adequate capacity for the additional flow.

During further refinement of the alignment of the concrete flume, it may be determined that specific reaches of the flume may be required to function as a retaining wall for the adjacent embankment. For those reaches, the uphill side wall of the flume will be designed to resist the lateral earth pressures. Also, a concrete cover or concrete ties may be utilized to span the side walls of the flume and to enhance the capability of the flume to resist the lateral earth pressures.

For the sections of the flume that will cross underneath existing roadways, the flume will be provided with a concrete cover, which will be designed to withstand live traffic loading and vertical earth pressures. The flume sections that are to be constructed slightly above grade will be supported on precast concrete sleepers or cast-in-place concrete foundations.

The preliminary cost estimate for this alternative feature is $1,567,100, which includes construction contingency, PED costs, and S&A costs. Refer to Plan Sheets 10 through 13 for the plan and profile of the gravity flume alignment and Plan Sheet 21 for cross section details of the flume.

Advantages associated with this alternative include the following:

- Concrete material is the most durable of the materials considered for the flume section and would provide for the greatest protection against falling trees and rocks.
- Reinforced concrete sections can be supported directly on existing grade with an underlying layer of leveling fill.

- The flume design can be easily adapted to accommodate the loading from road crossings and the loading due to lateral earth pressures from the adjacent hillside.
- The polyurea coating system can be factory applied on each precast flume section.
- This alternative is cheaper than either the fiberglass or the aluminum flume alternatives.

Disadvantages associated with this alternative include the following:

- A liner material is required to create a smooth surface.
- Joint construction will require field application of foam, sealant, and polyurea coating material.
- The 20 to 40-foot long precast segments are quite heavy, and if the flume is required to be elevated slightly above grade, precast concrete sleepers or cast-in-place concrete foundations would be required.

2.5.2.2 Gravity Flume Alternative 2

Alternative 2 is a fiberglass flume that would be constructed of fiberglass segments joined in the field. The interior surface of the flume would be polished fiberglass to provide for a smooth surface that would minimize injury to fish. Concrete encasement of the fiberglass flume will be required at the two road crossings to accommodate the traffic loading and soil overburden.

The preliminary cost estimate for this alternative feature is $2,318,200, which includes construction contingency, PED costs, and S&A costs. Refer to Plan Sheets 10 through 13 for the plan and profile of the gravity flume alignment and Plan Sheet 21 for cross section details of the flume.

Advantages associated with this alternative include the following:

- Sections are light weight, thus requiring lighter foundations
- Flush joint construction is easily accomplished.
- Elevated fiberglass flume sections would be easier to support than elevated concrete flume sections.

Disadvantages associated with this alternative include the following:

- Fiberglass is more susceptible to damage from falling trees than is concrete.
- Thermal expansion will be a significant factor in design.
- Unsupported fiberglass flume sections cannot span as far as concrete flume sections. The supporting foundations would be closer spaced than those required for the concrete flume alternative.
- The fiberglass flume cannot be used as a retaining wall. If this function were necessary, a separate concrete retaining wall would need to be constructed adjacent to the fiberglass flume.
- Fiberglass is the most costly of the materials that were considered for the flume construction.

2.5.2.3 Gravity Flume Alternative 3

Alternative 3 is an aluminum flume that would be constructed of aluminum segments joined in the field. The interior surface of the flume would be polished aluminum to provide for a smooth surface that would minimize injury to fish. Concrete encasement of the aluminum flume will be required at the two road crossings to accommodate the traffic loading and soil overburden.

The preliminary cost estimate for this alternative feature is $1,855,900, which includes construction contingency, PED costs, and S&A costs. Refer to Plan Sheets 10 through 13 for the plan and profile of the gravity flume alignment and Plan Sheet 21 for cross section details of the flume.

Advantages associated with this alternative include the following:

- Sections are light weight, thus requiring lighter foundations
- Flush joint construction is easily accomplished.
- Elevated aluminum flume sections would be easier to support than elevated concrete flume sections.

Disadvantages associated with this alternative include the following:

- Aluminum is more susceptible to damage from falling trees than is concrete.
- Thermal expansion will be a significant factor in design.
- Unsupported aluminum flume sections cannot span as far as concrete flume sections. The supporting foundations would be closer spaced than those required for the concrete flume alternative.
- The aluminum flume cannot be used as a retaining wall. If this function were necessary, a separate concrete retaining wall would need to be constructed adjacent to the aluminum flume.

2.5.2.4 Gravity Flume Alternative 4

Alternative 4 considered the possibility of eliminating the multi-level discharge system and the gravity flume system, and instead, extending the pressure bypass pipeline all the way to the transitional ponds. This would result in a 1,700 linear foot pressurized bypass pipeline alignment, from the Eicher screen to the transitional ponds. To replace the required operational flexibility that the multi-level discharge system provided, pinch valves are proposed to be constructed incrementally along the alignment of the extended pressure bypass pipeline to control the flow rate through the system.

Hydraulic analysis of the 1,700 linear foot pressure bypass system, with 24-inch pinch valves, concluded that approximately 70 pinch valves would be required under maximum reservoir pool conditions to control the flow through the system to within the range of 10 to 30 cfs. The assumption was made that the valve would operate such that the maximum allowable head loss through a single valve would be no more than 2 feet. Using a 24-inch valve, a 20-inch cone at the pinch location would provide for this head loss.

This alternative was not considered as part of the gravity flume alternatives for this 10% report for the following reasons:

- The sudden decrease in flow area at each of the pinch valve locations would be a potential site for debris to accumulate. Given that velocities through the pressure system may reach magnitudes as high as 10 fps, any debris that would accumulate within the pressure system would cause substantial injury to fish.

- Due to the large number of valves, the bypass system would likely require significantly more maintenance attention than would be the case with the gravity flume.

Figure 2. Proposed Gravity Flume Alignment at Upstream End. Photo looking downstream.

**Figure 3. Proposed Gravity Flume Alignment at Station 12+50.
Photo taken from USFS Road 2294 looking upstream.**

**Figure 4. Proposed Gravity Flume Alignment at Station 19+00.
Photo taken looking upstream along the steepest gradient of the alignment.**

Figure 5. Proposed Gravity Flume Alignment at Station 21+00.
Photo taken looking downstream along the steepest gradient of the alignment.

Figure 6. Proposed Gravity Flume Alignment at Station 24+50.
Photo looking downstream along substation access road.

2.6 Discharge Outlet

The discharge outlet is located at the terminus of the gravity flume. This feature of the bypass system consists of the necessary improvements to provide a safe and effective transition for fish as they are conveyed from the gravity flume to Wynoochee River. Given that the high energy flows from the flume will be transitioning from a supercritical flow regime to a subcritical flow regime, the discharge outlet also functions as an energy dissipater.

2.6.1 Assumptions

- The system must provide for a safe transition for fish as they move from the bypass system to the Wynoochee River.
- The discharge outlet is located on the flattest topography of the fish bypass facility, and is a strategic location for collecting and analyzing fish during fish survival testing of the entire bypass facility. Therefore, any discharge outlet system should be capable of being retrofit with the necessary collection equipment and should provide the necessary hydraulic characteristics that would enable fish to be safely and easily collected.

2.6.2 Alternatives

Two alternatives were considered to transition the fish from the gravity flume to the Wynoochee River, and are described in the following sections:

2.6.2.1 Discharge Outlet Alternative 1

Alternative 1 proposes to extend the gravity flume beyond the substation access road to the bankline of the Wynoochee River, where it would transition into a more natural open channel before discharging directly to the Wynoochee River. This discharge outlet alternative is therefore referred to as the direct discharge alternative. The point of discharge to the river is proposed just upstream of the USGS gauging station. This alternative was not evaluated for this project for the following reasons:

- In the vicinity of the proposed direct discharge, the Wynoochee River does not appear to provide the characteristics that would allow for successful fish acclimation after enduring the rigors of the fish bypass system. The river is quite shallow where the discharge would likely be constructed, therefore not providing adequate protection from predation.
- The gradient of the flume/open channel system at the point upstream of the direct discharge would likely be in excess of 14%, and would be conveying upwards of 30 cfs. Since the induction of a hydraulic jump within the flume/open channel section is prohibited by the design criteria, some means of dissipating the energy of the fluid flow would have to be constructed at the discharge to the river. As an alternative to allowing a hydraulic jump at the outlet, the flume could be constructed to free-fall into the river. However, there does not appear to be the necessary flow depth in the river to allow for this condition without causing injury to fish.
- Constructing the direct discharge to the river would likely require a hardened outfall system at the river bank due to the fact that upwards of 30 cfs would be discharged to the river during the migration window.
- It would be difficult to incorporate fish survival testing/collection facilities into this alternative.

2.6.2.2 Discharge Outlet Alternative 2

Alternative 2 will create a transitional pond system that will allow for flow to transition from a supercritical flow regime to a subcritical flow regime, while at the same time providing fish refuge for acclimation, prior to discharge to the river. Under this alternative the discharge outlet system would be comprised of several dependent features. These features are described below, in an upstream to downstream progression.

- The first cell of the transitional pond system will be constructed to receive and dissipate the energy from the gravity flume flows. The gravity flume will be designed to discharge the 10 to 30 cfs of bypass flow into the primary cell as a plunging jet, therefore dissipating energy without a formal hydraulic jump. The gradient of the flume upstream of this transitional pond would be constructed at approximately 3%. The associated Froude number for the range of possible flows is approximately 2.7. The water surface elevation in the primary cell would be 6 inches below the outlet elevation of the gravity flume. Where the flume discharges into the pond, the pond would be at least five feet deep so as to prevent injury to fish (Criterion #20). The remainder of the pond would be designed to have an average depth of two to three feet. The dimensions of the pond are assumed to be 20 feet wide by 20 feet long.

- The first cell of the transitional ponds will discharge into an open channel approximately 12 feet wide. Flows through this channel will maintain an average depth of 1.5 feet and a minimum velocity of 2 feet per second. The primary function of this channel will be as a site for trapping and collection of fish during testing. This function is described in more detail in a subsequent section of this report.
- The open channel will discharge into the second cell of the transitional ponds, thus connecting the two cells. The second cell will function as the formal transitional pond before fish are diverted to the river. It is proposed to incorporate the excavation that was conducted for the existing sedimentation pond, constructed in the early 1990’s, into the design of the second cell. The existing sedimentation pond is located southwest of the existing substation (refer to Plan Sheet 14).
- There will be two outlets from the second cell of the transitional pond system to the Wynoochee River. The primary outlet will be to a constructed swale and a stepped log weir channel which will discharge to the Wynoochee River just downstream of the existing USGS gauging station (refer to Figure 7). This outlet will be the passageway for fish to the Wynoochee River. The stepped log weir channel will be constructed along the last couple of hundred feet to traverse the steep gradient along the bank of the Wynoochee River. The other outlet will be a screened outlet that will be designed to drain off enough flow so as to maintain approximately 5 cfs in the open channel swale outlet. The second outlet will be a conventional piped outlet capable of conveying up to 30 cfs.

During future design phases of this alternative, the detailed geometry of the series of pools, channels, and swales that comprise this alternative will have to be analyzed in more detail. It will be imperative that dead spots, or eddies, be minimized in the system, especially in the primary transitional pond, so as to promote continuous downstream movement of fish.

The preliminary cost estimate for this alternative feature is $262,700, which includes construction contingency, PED costs, and S&A costs. Refer to Plan Sheets 13 and 14 (Appendix C) for plan drawings of this alternative.

Advantages associated with this alternative include the following:

- This alternative provides for a flexible, fish friendly transitional system from the gravity flume to the Wynoochee River. Migrating fish will have recovered from the rigors of the bypass system before moving into the riverine environment.
- Fish trapping facilities can easily be incorporated into this outlet system. The open channel connecting the two transitional ponds would be a suitable site for netting fish during testing of the bypass facility.
- This alternative utilizes an existing facility, namely the sedimentation pond, thus providing some cost savings.

Disadvantages associated with this alternative include the following:

- Implementation of this alternative will require construction activities within an environmentally sensitive area, specifically along the alignment of the low flow swale system, where there are several stands of old growth trees (see Figure 8) that will need to be avoided and protected during construction.

Figure 7. Wynoochee River at USGS Gage Station.
The proposed open channel outlet of the fish bypass facility is located just downstream.

Figure 8. Site of Proposed Transitional Ponds

2.7 Test Facilities

Two alternatives have been developed for the fish bypass survival testing facility. Both alternatives use the primary transitional pond and the connecting open channel that were proposed as part of Alternative 2 of the outlet discharge system. The open channel would be retrofitted to function as a sampling channel from which fish could be collected during testing. The width of the channel would be 12 feet, and the water depth would be approximately 1.5 feet. The length of the channel would be dependent on the specific collection techniques. Velocities in the sampling channel would be 2 fps to minimize potential fish injury during sampling. The survival testing facility alternatives are described in the following two sections.

2.7.1 Alternative 1 - Screen and Fish Crowder

Under this alternative, a vertical barrier screen would be placed at the downstream end of the sampling channel to capture fish as they move into the second transitional pond. The vertical barrier screen would be supported by a 3-foot wide footbridge and would either lower or swing into place. To gather fish from the channel, a mechanically operated crowder (another vertical screen) would be placed at the upstream end of the channel. It would then be moved downstream to within 24 inches of the barrier screen, thus crowding the fish into a confined 2-foot by 12-foot space in the channel. The fish would then be removed using a dip net. The length of the sampling channel would have to be a minimum of 30 feet in length so as to provide ample space to work. Screen material would be ¼” delta netting. The preliminary cost estimate for this alternative feature is $103,000, which includes construction contingency, PED costs, and S&A costs

2.7.2 Alternative 2 - Trap Net

The trap net alternative is significantly simpler and cheaper than Alternative 1. It employs a trap net in the sampling channel to capture fish. The trap net would be constructed of ¼ inch delta netting and four 2-foot diameter hoops and two 10-foot long wings. The net will be deployed in the channel by attaching the leads to poles approximately 10 feet downstream of the first cell of the transitional ponds. The length of the sampling channel would have to be a minimum of 40 feet in length to accommodate this alternative. The preliminary cost estimate for this alternative feature is $3,900, which includes construction contingency, PED costs, and S&A costs.

2.8 Supplementation Ponds

Two supplementation ponds are proposed to be constructed, one of which will be capable of holding 25,000 winter steelhead, and the other of which will be capable of holding 55,700 coho salmon. The pond footprints are programmed to be 30 x 60 feet, with 8-foot maximum depth. The ponds are to be designed to allow both volitional release and forced release of the juvenile salmonids. Water temperatures are generally below 12 degrees C during the time the fish are present. The ponds must be impervious to comply with NPDES permit conditions. Two methods of pond construction were considered:

- Cast-in place concrete pond liner construction
- Plastic pond liner construction

The cost and feasibility of these methods, the pond water supply, plus the use of natural materials in the ponds is evaluated below.

2.8.1 Water Supply

The water supply system will be conservatively designed to provide 500 to 700 gallons per minute to each supplementation pond. The primary water supply to the ponds will be a 1200-foot long 8-inch gravity flow surface water supply line using reservoir water from the existing penstock, delivered to the head end of each pond. A secondary supply utilizing pumps from the river below the dam will be provided in the event that the penstock is dewatered. The river water pump station will have a duplex lead lag type control system, to activate the lag pump if the lead pump stops producing flow. The location and configuration of the pump station will be investigated further for the next progress submittal.

A 30-inch diameter packed column will be provided on the inlet to each pond to ensure adequate oxygenation and dissolved gas pressure levels in the water supply. The flow into each pond will be diffused by a supply header to provide uniform flow through the pond and avoid creating a cascading attraction flow.

2.8.2 Pond Construction

As mentioned above, in order to meet current NPDES requirements, the ponds must be constructed of impervious materials to prevent seepage into groundwater or streams. The use of cast-in-place concrete, gunite, or plastic liner material are proven pond construction methods. Other pond construction criteria include:

- An outlet structure with screens and stop logs for water level and volitional release control
- Sloping bottoms towards the outlet structure for positive drainage and dewatering
- A 2 foot by 2 foot concrete center channel the length of the pond for collecting and crowding fish that do not release volitionally
- Water supply flow control valves
- Fenced pond edges to discourage predation by wading birds and swimming mammals
- Bird netting canopy to discourage predation by flying and swimming birds
- Provisions for cleaning fish wastes, and uneaten food from ponds
- Optional additions include the use of cobbles and woody debris placed on the pond bottom and shade provided by trees or camouflage netting at pond edges to simulate natural conditions
- WDFW may request or require an automatic fish counting system to track the number of fish released volitionally. Separate counting devices may be required for each pond since there are two different species being released

Regardless of which construction method is used, large shot rock may exist at the pond site and will need to be removed during pond excavation.

In recent attempts to improve survival after fish are released, fisheries scientists have explored the use of natural substrates such as cobble rock and woody debris placed on pond bottoms to create a more natural environment. These trials have shown that fish from these types of ponds do adapt and survive better after release. However, the use of natural materials in the ponds makes cleaning them more difficult.

Disposal of the cleaning waste is another important consideration. Often, cleaning waste is dewatered and hauled off to an approved disposal site or agricultural area. With a 30-foot width, these ponds may be small enough to clean with vacuum equipment from the pool edges.

An automatic fish counter allows tracking of volitionally released fish. The system consists of a pipe mounted scanner and a central processing unit. Scanners cost about $3,500 to $4,500 each, and a CPU capable of tracking up to 4 scanners is $5,200. More discussion with WDFW is required in order to establish the need for and possibly develop the design of this system. The cost of this system was included in the estimate of the supplementation pond construction.

Mechanical system components for the supplementation ponds include drain valves, flow control elements such as weirs and valves, and associated pumps and automation controls.

2.8.3 Construction Costs

Conceptual level cost estimates were developed for the two types of pond construction. Alternative 1 provides costs for constructing the ponds of concrete. This type of construction is more costly, and is likely to be more durable than a plastic lined pond. For comparison purposes the costs for cobbles, shaded edges, and woody debris were not included in the estimate for the concrete pond, although these features could easily be added. The preliminary cost estimate for this alternative feature is $486,700, which includes construction contingency, PED costs, and S&A costs.

Alternative 2 provides costs for constructing ponds that retain a concrete center channel and outlet structure, with a 60 mil plastic liner containing the rest of the pond. The preliminary cost estimate for this alternative feature is $481,200, which includes construction contingency, PED costs, and S&A costs This alternative also includes $16,000 for the cost of adding natural features, such as shaded edges, cobbles, and woody debris to the pond bottom.

2.9 Fish Trap/Haul Facility Modifications

The existing Wynoochee Dam adult fish trap has four major components: a fish crowder, a false weir, a flume, and a hopper. Figure 9 shows the relative location of each of these components.

In the past, sorting of fish has been done by TPU based on wild stock vs. hatchery stock for both steelhead and coho. The existing trap needs to be modified to allow for more comprehensive sorting of wild fish and hatchery fish stocks. The modifications may include changes in the sorting flume and installation of two additional holding tanks. Other modifications may include the extension of the operator's platform to direct fish into the appropriate tanks and the installation of new lifting devices to assist in truck loading. The hauling truck may need to be modified, as well, to match the hopper for the water-to-water transfers.

It has not, however, been currently established what fish will be sorted, nor what the sorting parameters will be. Due to the fact that the sorting protocols have not yet been fully defined, specific design criteria and cost estimates for the facility modifications were not developed at this stage. The assumption was therefore made that sorting will be done for only one parameter at a time (i.e. age, species, or origin), thus requiring a system of two tanks with the requisite facilities to conduct the sorting. Once the sorting criteria are better defined, detailed facility modification recommendations can be analyzed and designed. The following sections of this report provide brief, general descriptions of the function of each component and the modifications that are necessary based on the one parameter assumption.

2.9.1 Fish Crowder

The fish crowder retains fish until they are moved to the hopper or transportation trucks. Fish enter the crowder through the flow outlet. To operate the crowder, the tank is constricted by moving the screen toward the false weir. Fish exit the crowder as they are forced to swim over the false weir. Figure 10 shows these two components of the facility.

2.9.2 False Weir

Fish are attracted to the false weir by upwelling water at the peak of the weir that falls into the fish crowder. Fish jump up the weir, but end up sliding down the backside of the weir into the sorting flume and ultimately towards the sorting gate and hopper. Currently, workers stand over the weir and capture the fish as they attempt to jump over it. If workers select a fish, the fish is captured, then handed to another person where they are carried by hand either to a transport truck or place in the PVC pipe that directs the fish to the hopper. This fish handling is quite strenuous with little room to work. There is need for an improved platform or other structure for workers to stand on and reduce strain. Figure 11 shows this component of the trap/haul facility.

2.9.3 Fish Flume and Sorting Gate

The fish slide down the flume in less than 1" of water (fish can swim upstream in depths greater than 1 inch) and are either directed to the hopper or to the river. Figure 12 shows the existing fish flume and sorting gate, and Figure 13 shows a close up of the sorting gate.

An additional fish tank and sorting mechanism are needed due to additional fish sorting needs and to reduce worker strain. It is recommended that the existing PVC pipe be removed and that the additional fish tank be constructed below where the pipe was located. An additional sorting gate is recommended for installation in the flume so as to direct fish into the new tank. Alternatively, a single sorting gate could be installed that directs fish to each of the three directions (i.e. new fish tank, fish hopper, river).

2.9.4 Hopper

Once the hopper is full of fish, the hopper is raised (Figure 14) and moved over a truck where the bottom of the hopper is opened, dumping the fish into the truck. This is only used for transporting adult salmon and steelhead upstream of the dam. Currently, the WDFW truck is unable to handle the load released from the hopper. Therefore, a system will need to be designed that will lift the proposed additional fish tank from the position adjacent to the sorting flume and onto the truck for transport. This system would likely be a mobile crane or other such hoisting mechanism.

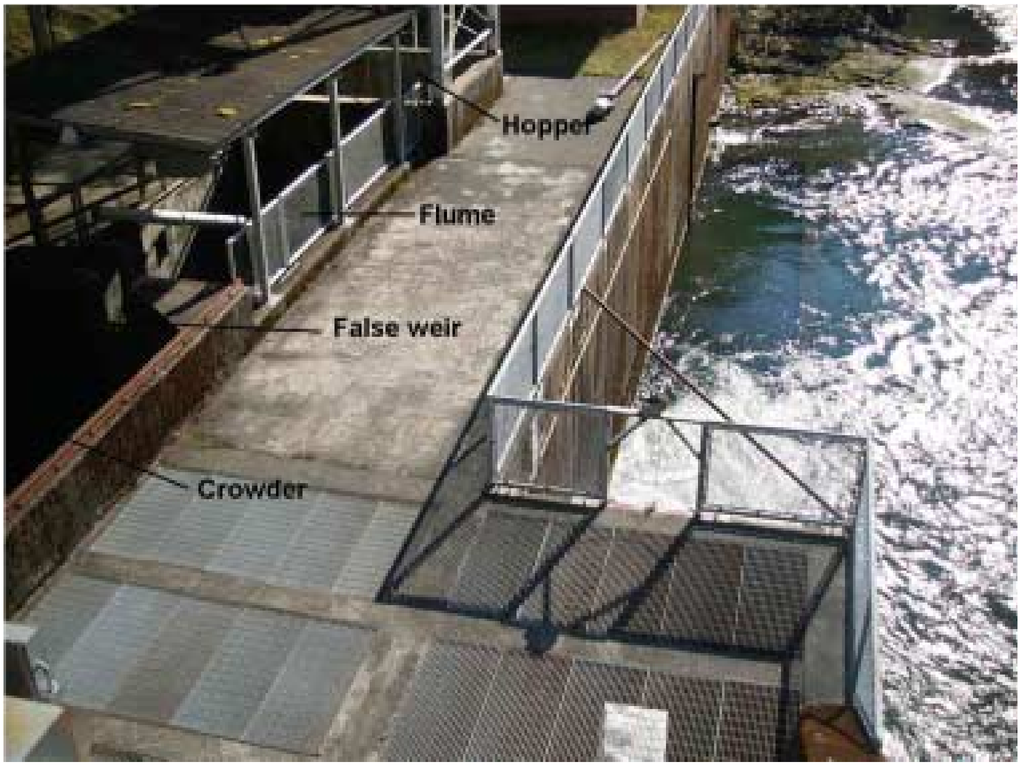

Figure 9. Wynoochee Dam Adult Fish Trap Facility

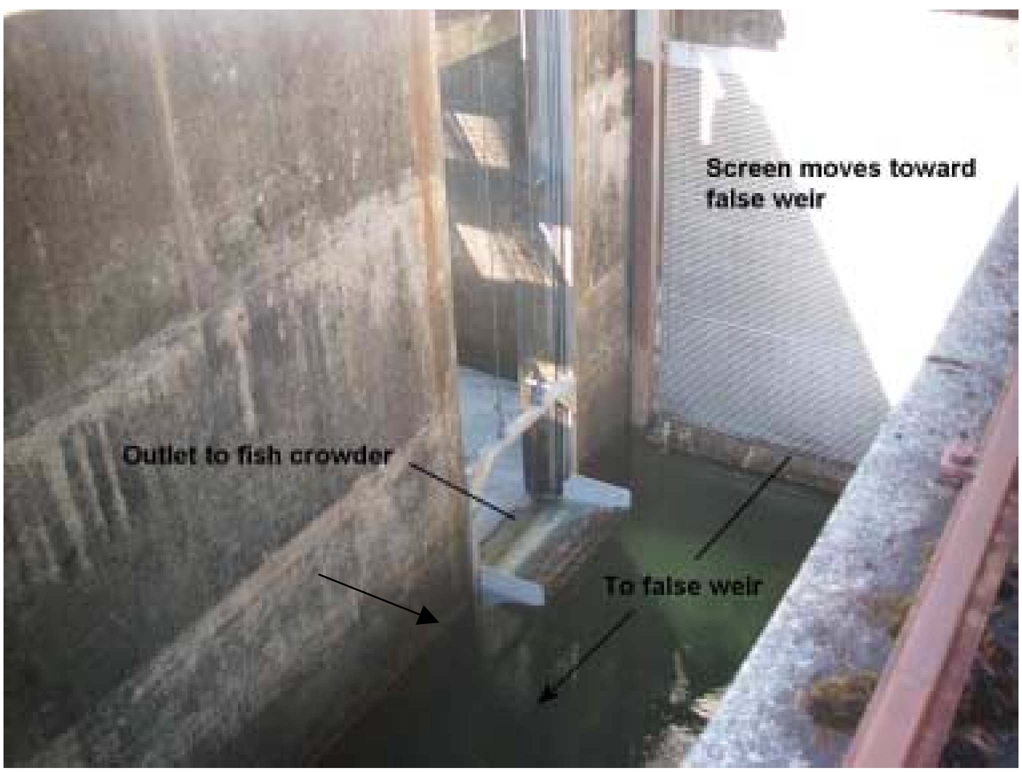

Figure 10. Fish Crowder.

Figure 11. False Weir.

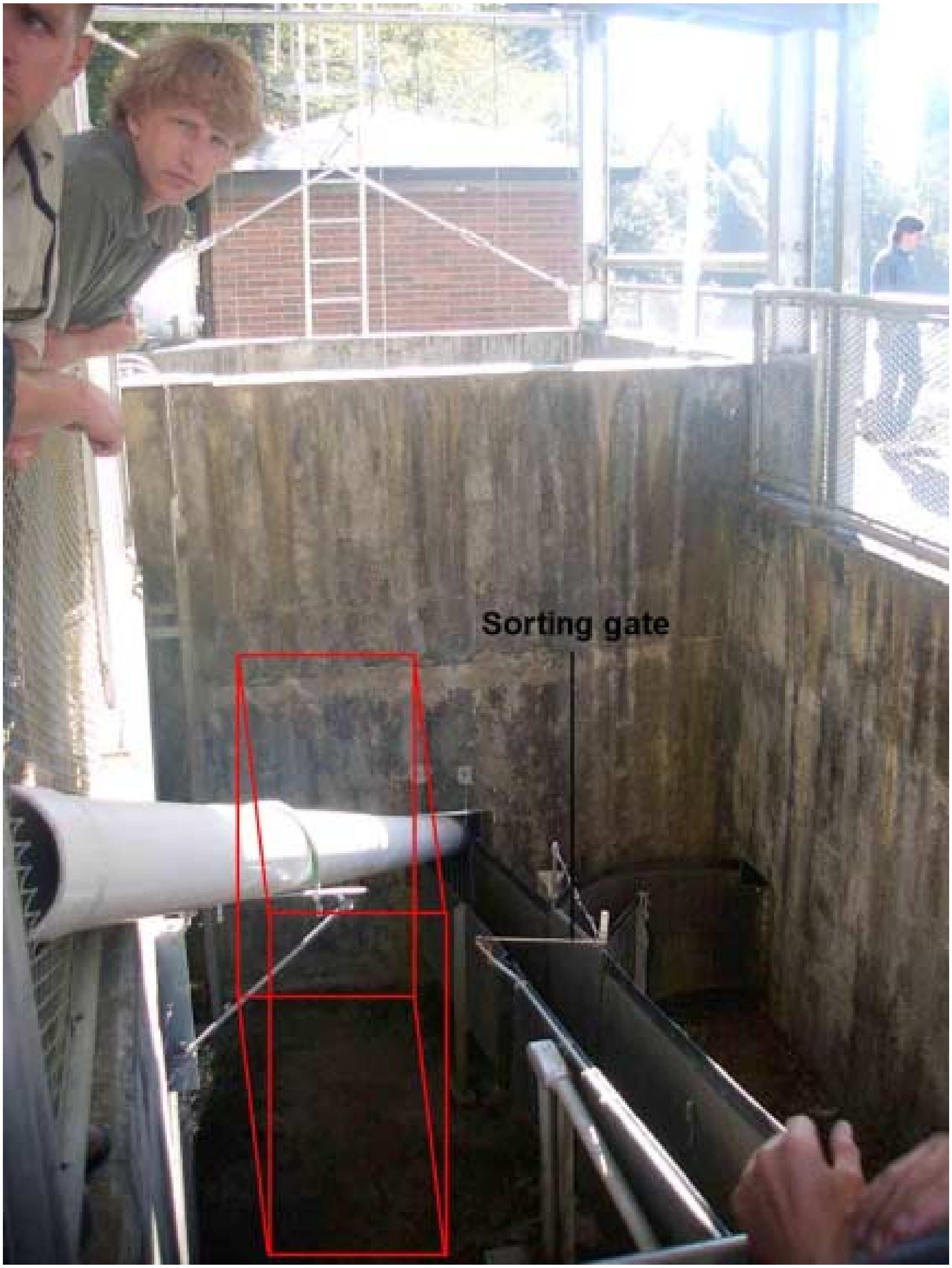

Figure 12. Fish Flume and Sorting Gate
The red box indicates the location of the additional fish tank that is recommended.

Figure 13. Fish Flume and Sorting Gate.

Figure 14 Fish Trap and Hopper

The flume and sorting gate are located under the roof to the left of the group of people. The hopper is in the lifted position.

Figure 15. Dam and Outflow at Fish Trap

Figure 16. Low Flow Notch at Upstream Fish Trap

2.10 Control Systems

Due to its remote location, Wynoochee Dam is lightly staffed and typically only one person is available for operational procedures at any given time. Therefore, there is a need to automate and control as many aspects of this fish bypass system as is feasibly possible. To accomplish this, close coordination will need to occur between all relevant parties to ensure the proper design of all features to be compatible with TPU's control system.

Mechanical elements included in the control system will need to be closely coordinated with electrical elements such as pressure sensors, limit switches, and flow meters. This coordination will allow for automated control of the movement of the mechanical systems. For example, an elapsed time meter and pressure differential switch can be connected in series to change position of the Eicher Screen for cleaning during periods of migration.

To date, no specific alternatives have been identified for control system requirements. However, an appropriate lump sum unit cost for control systems and instrumentation was included in the cost estimate of each project feature alternative that is anticipated to require automation. A lump sum unit cost for power and telemetry was also included in the cost estimate of these project alternative features.

3. CONSTRUCTION COST ESTIMATE SUMMARY

Table 4 presents a summary of the 10% level cost estimates for each alternative of each design feature of the Wynoochee Dam fish bypass facility. Refer to Appendix D of this report for the individual spreadsheet cost estimates for each design feature alternative. All costs are expressed as 2003 dollars. Table 4 includes a range of costs for the sum of all of the alternative features. As described in the text of this report, cost estimates for the modifications at the adult fish trap facility were not determined, and therefore, costs for this feature are not included in Table 4. The preliminary cost estimate for the sum of all of the lowest cost alternatives is $5,408,300, and the preliminary cost estimate for the sum of all of the highest cost alternatives is $8,661,800.

The estimated construction costs shown in Table 4 include all construction elements and a 35% construction contingency. The planning, engineering and design (PED) subtotal is based on 15% of the estimated construction cost and includes money that is allocated for future design activities for project implementation. The supervisory and administration (S&A) subtotal is based on 12% of the estimated construction cost and includes money that is allocated for federal construction management related activities. At this time, real estate costs and permitting costs were not included in the cost estimates. The preliminary cost estimate for a specific alternative feature is therefore a summation of the estimated construction costs, PED costs, and S&A costs.

Annual operation and maintenance (O&M) costs for each project alternative feature were based on 2% of the estimated construction cost. O&M costs were not included in the summation of costs that make up the preliminary alternative cost estimates, and are therefore stand-alone costs.

Table 4. Summary of Estimated Costs for Alternative Design Features						
Design Feature and Alternative	**Estimated Construction Cost**	**PED**	**S&A**	**Real Estate Costs**	**Prelimary Alternative Cost Estimate**	**O&M**
Intake Wetwell and Gateshaft						
Alternative 1 (Seal Opening)	$21,700	$3,300	$2,600	$0	*$27,600*	$400
Alternative 2 (Modify Opening)	$189,000	$28,400	$22,700	$0	$240,000	$3,800
Penstock Eicher Screen						
Alternative 1 (Bypass Round)	$2,617,200	$392,600	$314,100	$0	$3,323,900	$52,300
Alternative 2 (Bypass Square)	$1,795,100	$269,300	$215,400	$0	$2,279,800	$35,900
Alternative 3 (Removable Section)	$1,246,500	$187,000	$149,600	$0	*$1,583,100*	$24,900
Pressure Bypass Pipe						
Alternative 1 (24” HDPE)	$288,600	$43,300	$34,600	$0	*$366,600*	$5,800
Multi-Level Discharge System						
Alternative 1 (Six-Shooter)	$1,228,900	$184,300	$147,500	$0	$1,560,700	$24,600
Alternative 2 (U-Shaped Sections)	$878,900	$131,800	$105,500	$0	*$1,116,100*	$17,600
Gravity Flume						
Alternative 1 (Concrete)	$1,233,900	$185,100	$148,100	$0	*$1,567,100*	$24,700
Alternative 2 (Fiberglass)	$1,825,300	$273,800	$219,000	$0	$2,318,200	$36,500
Alternative 3 (Aluminum)	$1,461,400	$219,200	$175,400	$0	$1,855,900	$29,200
Discharge Outlet (Including Trapping Facilities)						
Alternative 1 (Direct Discharge)	N/a	N/a	N/a	N/a	N/a	N/a
Alternative 2 (Transitional Ponds)	$206,800	$31,000	$24,800	$0	*$262,700*	$4,100
Test Facilities						
Alternative 1 (Fish Crowder)	$81,100	$12,200	$9,700	$0	$103,000	$1,600
Alternative 2 (Trap Net)	$3,000	$500	$400	$0	*$3,900*	$0
Supplementation Ponds						
Alternative 1 (Concrete)	$383,200	$57,500	$46,000	$0	$486,700	$7,700
Alternative 2 (Plastic Liner)	$378,900	$56,800	$45,500	$0	*$481,200*	$7,600
Sum of Preliminary Costs for Least Costly Alternatives					**$5,408,300**	
Sum of Preliminary Costs for Most Costly Alternatives					**$8,661,800**	

This page intentionally left blank.

4. REFERENCES

Adam, Pieter, Donald P. Jarrett, Allan C. Solonsky, Larry Swenson. Development of an Eicher Screen at the Elwha Dam Hydroelectric Project. Published in Waterpower '91.

City of Tacoma Department of Public Utilities. Wynoochee Dam Hydroelectric Project Record Drawings. 1991.

Dunn, C.A. Evaluation of Downstream Fish Passage through Multi-Level Outlet Pipes at Wynoochee Dam. Washington State Department of Fisheries, Progress Report No. 45, U.S. Army Corps Contract No. DACW 67-76-C-006 and 0057. 1978.

National Marine Fisheries Service – Environmental and Technical Services Division. NMFS Proposed Recovery Plan Appendix D - Juvenile Fish Screen Criteria. Revised December 21, 1994.

Tetra Tech, Inc. Wynoochee Dam, Fish By-Pass PMR/EA Review Comments. October 2001.

United States Army Corps of Engineers (USACE). Wynoochee Dam Section 1135 Fish Restoration Report; Project Modification Report and Environmental Assessment. May 1998.

Winchell, Fred C. and Charles Sullivan. Evaluation of an Eicher Screen at Elwha Dam. Published in Waterpower '91.

Wynoochee Dam Section 1135, Interim Design Report Scope of Work. DACA67-02-D-2009 Delivery Order 2.

This page intentionally left blank.

APPENDICES

Appendix A – Biological and Hydraulic Design Criteria

Appendix B – Hydraulic Analyses Appendix

Appendix C – 10% Plan Sheets

Appendix D – 10% Cost Estimates

Appendix E – Preliminary Geotechnical Engineering Report

Appendix F – T.W. Sullivan Hydroelectric Plant 12/09/02 Site Visit – Field Notes and Photographs

Appendix G – Hatchery and Wild Fish Management Background Discussion

Appendix H – Eicher Screen Reference Articles

This page intentionally left blank.